Presented at the 4th International Lime Congress, Hershey,Pennsylvania 9/22/78

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Lime Treatment of Sewage Sludge

Introduction

In recent years the treatment of sewage sludge with quick lime has become an interesting alternative method for the final disposition of the sludge as a liming material. This idea is not new, but there are a few facts which recently have added to the interest in the method. The increased demand for improved treatment of municipal waste water from the environmental authorities is compelling the sewage plants to further measures. As a result the amount of sludge is increasing and synchronously the simple dumping of the sludge is restricted for the same reason. With modern technology, with better presses and the use of flocculants, it has been possible to raise the total solids of the dewatered sludge, which has made it possible to stabilize the sludge to a granular hygienic structure.

This report describes the method, its place in the system, and its realization in the sewage plants. The slaking of the lime in the sludge is followed by a temperature rise, evaporation and an increase of the total solid, which is discussed and compared with observations. The economy of the method is satisfactory, a satisfactory hygiene is obtained with moderate quantities of lime and at modest costs for the sewage plants. At a few plants more lime is added than necessary for a good hygiene in order to produce a liming product with a higher lime content.

Sludge volumes

Principally, the treatment of municipal waste water is a separation process where soluble and solid matters are removed from the water to such an extent that the water may be let out into a receiving water system without any sanitary inconvenience. The treatment usually consists of two to three or more processes (fig. 1) through which the waste water consecutively is flowing, and which all are producing sludge. The better the treatment; the more processing stages passed, the larger the quantity of sludge will be.

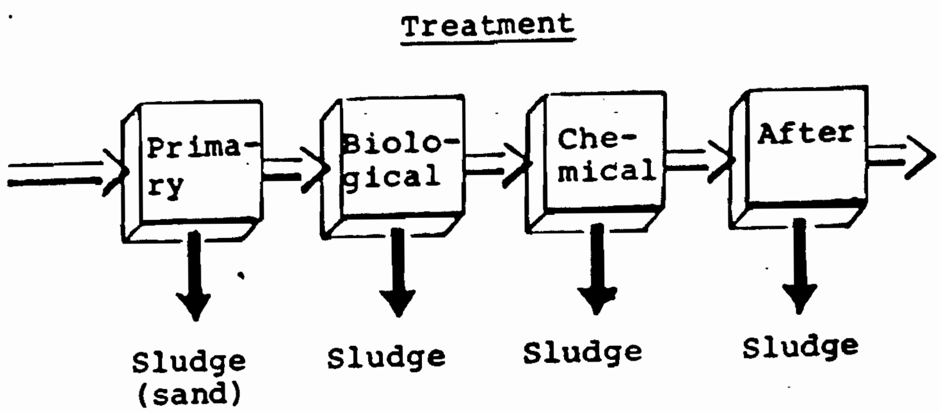


Fig. 1

The sludge volume as total solids (TS) may be estimated from table 1.

Table 1 - Sludge volumes

Treatment	Accumulated TS g/p.d.	TS kg/p.y.
1 Primary	60	22
1+2 Biological	95	35
1+2+3 Chemical	120	44

The figures are the accumulated volumes and may vary between the plants. As can be seen, there is a considerable increase in volume with three stages and would be still larger if lime is used for the chemical precipitation.

In Sweden, as an example, the volume of sludge has increased in the last 10 years (1967-1977) by 90% and is now 41 kg/p.y. At the same time the number of connected persons has increased only by the half or 45% from 69% to 100% of the total urbanized area.

Ultimate disposal

The rapid increase in sludge volume has caused a correspondingly increased problem for the ultimate or final disposal. In table 2 the final disposal is shown for 1977 and 1973.

The comparison for the two years 1977 and 1973 gives a strong trend towards the use in farming. The use for landscaping or dumping has decreased in spite of the considerable increase in volume, 22%. This decrease may be regarded as a result of the environmental protection efforts. It is expected that these trends will continue and that several sewage plants will have to alter their disposition for the final disposal.

Table 2 - Final Disposal

Use	1977	1973
Farming	41	21
Landscaping	10	17
Dump	48	56
Incineration	.3	2
Others	.4	5
Sludge 1000 tons TS	280	230

An example of a change of the final disposal from dumping to a re-use of the sludge in farming is the Rya sewage plant in Gothenburg on the Swedish West Coast. The plant was constructed 1971-1972 for 630,000 persons (pe) with biological treatment without primary sedimentation. In the first years the dewatered sludge was dumped while attempts were made to dry the sludge before transport and re-use in farming. This attempt failed, and the plant had to choose between other methods for re-use. The choice was lime stabilization of dewatered sludge.

Although a number of smaller plants already had applied the lime stabilization of dewatered sludge, the Rya plant was the first large plant. This created a considerable interest in the method and in the economy. The most interesting fact is, however, that quick lime stabilization was chosen in stead of aerobic or anaerobic stabilization, the usual methods for sludge to be used in farming.

2. Quick lime stabilization of sludge

The quick lime stabilization method is shown in principle in fig.2. After thickening and adding of flocculants, the sludge is dewatered and brought to a mixer together with finely crushed quick lime. The mix goes to storage and vapor stripping.

Fig. 2

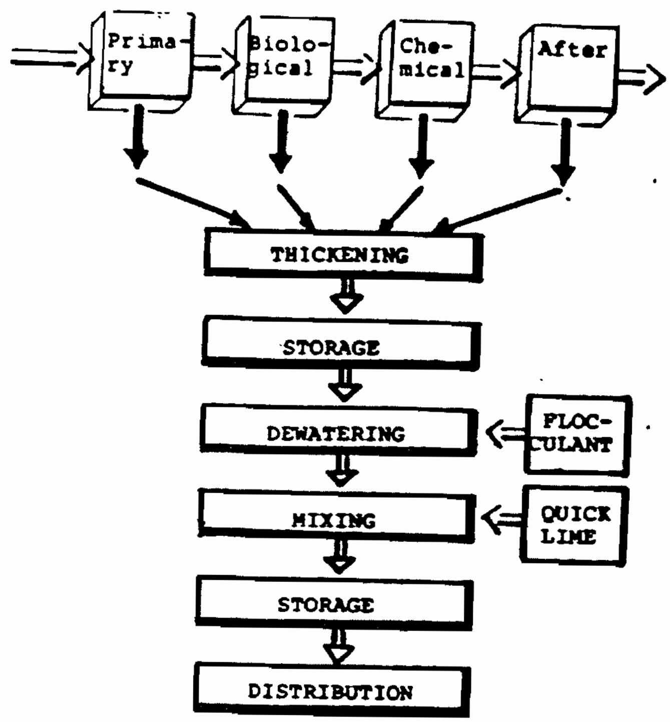


Fig. 3 shows the machinery at the Rya plant. Dewatered sludge is fed to the mixer over a belt conveyor machinery, balance and a screw. The lime is fed with a screw with an adjustable drive connected to the sludge balance. The lime feed is 500 kg lime per ton sludge TS or 100 kg per m^3 sludge with 20% TS. A belt conveyor takes the mix to a storage. The transportation to storage is now being completed with belt conveyors.

Fig. 3

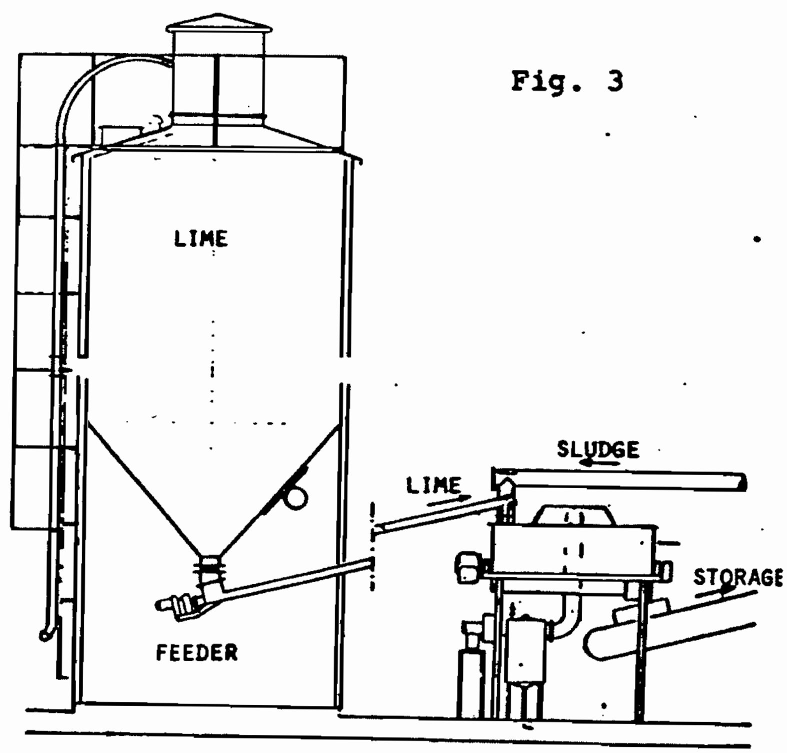


Fig. 4

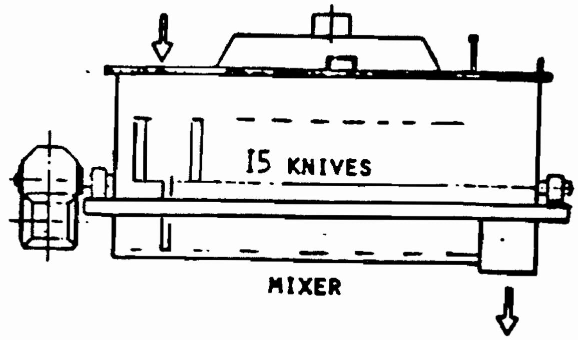


Fig. 4 shows the mixer; it is a single shaft mixer with 15 blades, slightly inclined to give a movement to the mix. The reaction between the quick lime and the water in the sludge starts already in the mixer in the same way as when producing dry hydrate. The temperature is rising followed by a strong evaporation and a change in the consistency of the sludge similar to the coagulation when clay is stabilized with lime. Because of this the mixer should be a simple machine to avoid trouble in the performance.

The lime stabilizing causes a real change in the consistency. The sludge becomes friable and may be distributed with an ordinary manure spreader common on every farm. The spreading might be done by the farmers themselves, although contract work is common in many areas.

3. Lime slaking in sludge

When mixing lime and sludge the lime is slaked to hydrate with generation of energy, 1160 kJ/kg CaO. The temperature of the sludge is raisedto a maximum depending on the quantity of lime to the volume of water and the reactivity of the lime. A standard quality quick lime with 90-95% available or free lime (ASTM) is slaked completely within 5-10 min.

In fig. 5 the two upper curves represent the calculated maximum temperature, provided there is no loss of energy, as a function of the lime to water ratio. The wet slaking methods ASTM and DIN, commonly used in the laboratory to determine the reactivity, are marked in the diagram. The observed maximum temperature is lower than the calculated due to energy loss and because of physical reasons a small part of the lime may have low reactivity and not contribute to the maximum temperature. The lower curve is

Fig. 5

an example of lime slaking in sludge under normal plant conditions. The energy loss is larger than in the laboratory and is increasing at higher temperatures. The fig. 5 also shows that the boiling temperature 100 °C is reached with 35-40 kg lime per 100 kg water depending on the water temperature 10-15 °C and the circumstances.

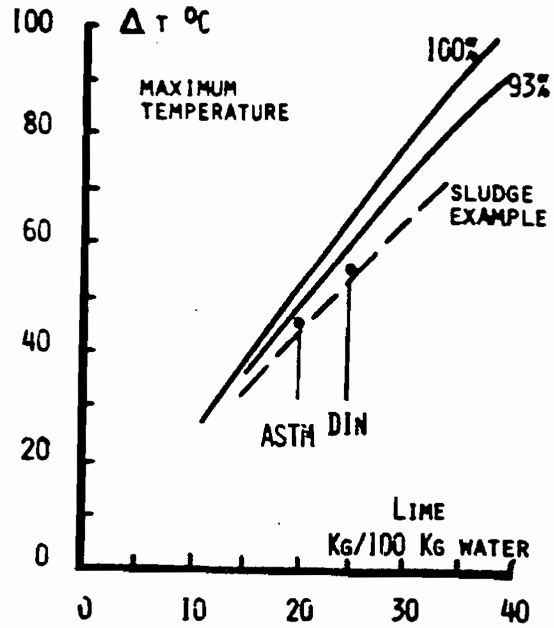
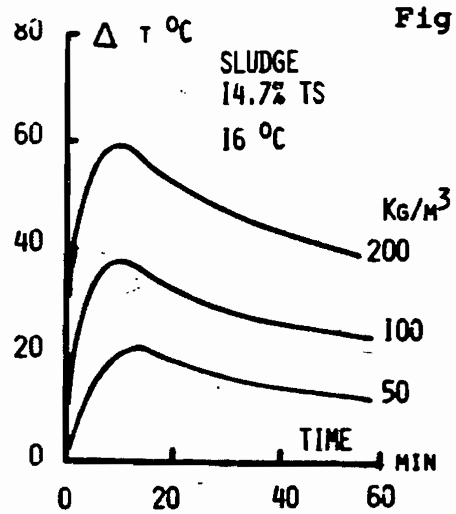


Fig. 5

When mixing lime and sludge the temperature rise is followed by a strong evaporation. The water is vanishing as vapor in the mixer and later during storing and the TS is increasing. The temperature rise is limited by the loss of heat to the environment.

Fig. 6 shows a serie of temperature measurements in 1/2 scale in a plant when slaking lime with a mixed biological and chemical sludge. The addition of lime was 50, 100 and 200 kg per m^3 sludge with 14.7% at 16.0 °C. The lime to water ratios are respectively 5.9, 11.7 and 23.4 kg lime per 100 kg water. The temperature rise is similar to wet slaking in the laboratory, slightly slower for the smaller lime additions, with a maximum after 10-20 min.

Fig. 6



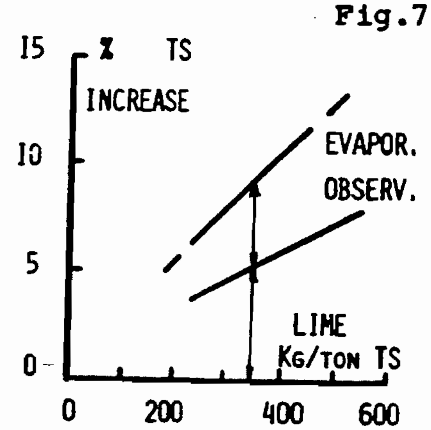
Temperature rise

The water evaporation rate is larger in the beginning of the slaking. Within 20 min. corresponding to the maximum temperature or slightly after, about 60% of the total evaporation in the first hour has taken place. This gradual disappearance of the water increases the temperature rise, which may be calculated to 2-3 °C up to the maximum temperature. The mixing of lime and sludge is, however, rather incomplete in the beginning why too high temperatures may be observed before the mixing is complete. In these measurements an excess temperature is observed up to about 40 °C rise or 55 °C in the mix, but at higher temperature the energy loss takes the lead, and the temperature maximum will be lower. The temperature curve will greatly depend on the design of the plant, the lime and other circumstances.

Total solid increase

The lime addition increases the sludge volume and the content of total solid. Since the solubility of lime hydrate in water is only 1g per litre or 1 kg per m^3, the whole lime addition may be regarded as an increase of the total solid, after multiplying the lime weight with the factor 1.3. This increase, together with the increase due to the water evaporation, might be considerable.

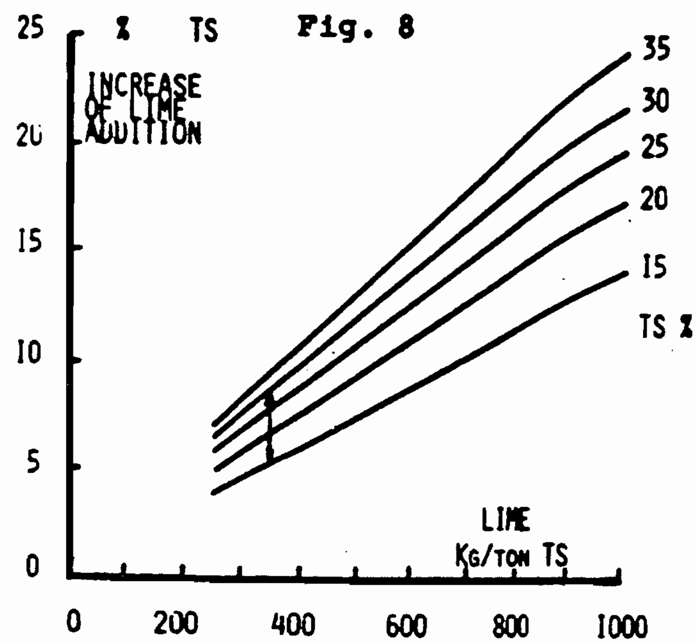
Fig.7



In fig. 7 the upper curve represents a mean value of measurement at a number of plants of the total solids two hours after the mixing. The lime addition is 250-450 kg per ton TS, the TS in the sludge is 15%. The lime addition as hydrate is represented by the lower curve. The difference represents the increase due to evaporation, which in this case is about 3/4 of the rise due to the lime addition only. At higher additions and at higher temperature the effect might be larger. The evaporation, however, is very much depending on the local circumstances. The observation in fig. 7 therefore is an example from a limited number of plants. The lower curve in fig. 7 shows the increase of TS at 15% TS in the incoming sludge.

Fig. 8 represents the increase of TS due only to the lime addition up to 35% TS in the incoming sludge. The evaporation difference in the previous fig.7 is laid in. As can be seen, the effect of the evaporation is the same as if the ingoing TS had been doubled from 15% to 30%. The evaporation is considerable, and it is important to take advantage of this effect in the plant by suitable measures, such as a good ventilation, etc.

Fig. 8



4. <u>The use of lime stabilized sludge</u>

The use of lime stabilized sludge is governed by two factors

- permissible quantity of sludge per surface unit
- the need and price of lime per surface unit

4 a) <u>Public health considerations</u>

The use of sludge for agriculture purpose is regulated by the health authorities. In Sweden the maximum permissible sludge quantity per area unit is 0,1 kg TS/m^2 year or 0,5 kg TS/m^2, 5 years. The practical measure is 1 t TS/ha year (1 ha = 10,000m^2) or 5 t TS/ha, 5 years, or approx. 1,000 lbs TS/acre, year or 5,000 lbs TS/acre, 5 years. These figures have been approved for aerobic and anaerobic stabilized sludge and are valid also to lime stabilized sludge.

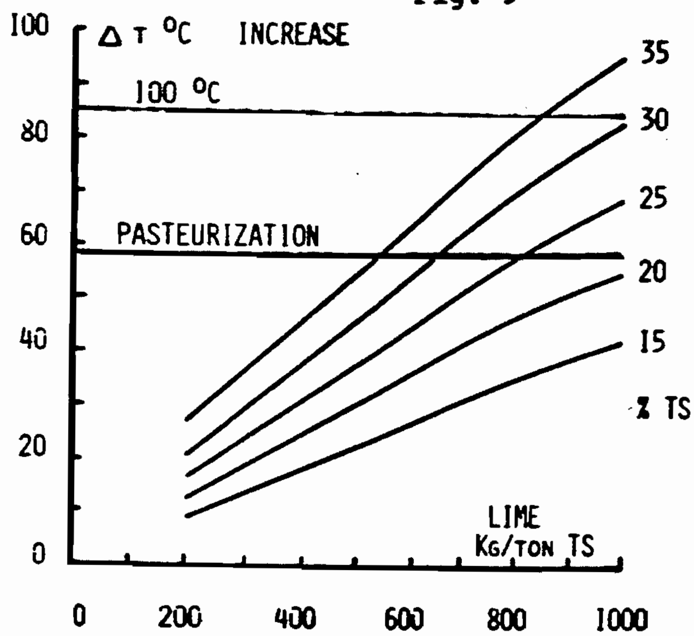
The sanitary effect of quick lime on sludge is of two kinds. That from a high pH for a long time and from a high temperature and from a combination of these two effects.

<u>The effect of high pH</u> on pathogenes is considered to be efficient. This subject has been extensively studied for waste water effluents and also for sludge up to pH 11.5 and 12 (1) (2) arrived at when liming sludge before dewatering. When treating the sludge with quick lime the pH rapidly rises to its maximum about 12.4 with the addition of 150-200 kg CaO/1,000 kg TS and maintains this high pH at an

addition of about 200 kg CaO/1,000 kg TS (3) which for other reasons is the lowest quantity for the practical stabilization. Studies (3) on sludge from the Rya plant, mentioned above, and some other plants indicates that all coli bacteria rapidly disappear when pH reaches 12 and above. Investigations of stabilized sludge indicate that all bacteria and virus have been removed. The action of a high pH is considered to inactivate parasite eggs but not killing them. However, the action of a high pH for a very long time, years, is not known.

The effect of temperature on pathogenes and parasites is well known. Pasteurization is obtained at 72-75 °C where also parasite eggs are killed. At 100 °C and above the sludge may be sterilized.

Fig. 9



In fig. 9 the diagram shows the temperature rise Δ t °C which might be expected under practical conditions, exemplified in the foregoing diagrams, as a function of the quick lime addition at different TS in the sludge. The pasteurization temperature has been entered as the lower line and the 100 °C as the upper line assuming 15 °C in the sludge. An average dewatered sludge of 22-25% TS will reach the pasteurization temperature with 800-1,000 kg lime/1,000 kg TS. At a lower TS, for example, 15-20% after dewatering the lime requirement to obtain pasteurization will be very much higher and consequently much more expensive. If pasteurization is the aim of the lime treatment, a good dewatering should be presupposed to keep down the lime requirement. The importance of the dewatering is obvious, for example, if the TS is increased to 30%, pasteurization is reached with only 650 kg lime.

The combined effect of high pH for a long time and a high temperature is not sufficiently known.

From the public health point of view there are three alternatives of lime addition:

1. Low addition. 200-500 kg/ton TS which should be considered the standard alternative. Hygienic condition mainly by high pH, 12.4, for a long time, month, years. The lime addition may vary with the lime requirement of the soil in the market area.

2. Pasteurization addition. 800-1,000 kg lime/ton TS or enough to reach 75 °C. Hygienic condition by 75 °C temperature for a short time, 15-30 min. and by a high pH for a long time.

3. Large addition to reach 100 °C for a short time or 75 °C for a longer time and a high pH for a long time.

The necessary lime addition depends on local circumstances. Normally an acceptable hygiene should be obtained with an addition of 200-500 kg lime per ton TS. This dose could easily be increased to pasteurization, should this temporarily be necessary.

4 b) Agricultural considerations

The lowest lime quantity for good stabilization of the sludge is about 200-250 kg lime per ton TS which gives a friable material that could be spread with an ordinary manure distributor. A higher lime addition might be advantageous and expedite the spreading. The stabilized sludge can be stored in open air also in wet climate and during the winter; thus it can easily be stored between the distributing seasons.

The maximum permissible sludge per surface unit and the minimum lime requirement for a good stabilization allows for 200-250 kg lime per 10,000 m^2 (or lbs/acre). This quantity is within the range of the normal maintenance liming to maintain the CaO content in the soil. Should the lime requirement be larger, the sludge has to be stabilized with more lime. This is the reason for the 500 kg per ton TS at the Rya plant in Gothenburg, as well as the practical fact that the farmer wants to lime just once.

Stabilization with larger quantities than 200-500 kg/ton TS in order to make the sludge more competitive as a liming material compared with limestone is made at a few plants. The economic reason behind is a comparison between the 50% CaO content in limestone and the low content in the sludge considered only as a liming material without any regard of its organic content. With 500 kg lime/ton TS the stabilized sludge will have a CaO content of 30% dry but only 15% wet. With 1,000 kg lime/ton TS the CaO content is 43% dry and 33% wet and is able to compete when the farmers are paying only for the CaO.

5. Conclusions

The quick lime stabilization of sludge offers a comparatively inexpensive way to convert the sludge to a hygienic liming and fertilizing material. The investment costs in the plant are very modest compared with other methods to prepare the sludge for agricultural use, long time aerobic or anaerobic stabilization. The distribution of the lime stabilized sludge is simple and can be done with ordinary machinery or by contractors. The storing between the distribution seasons is simple and inexpensive. There is no smell and other difficulties encountered when handling other forms of sludge.

The lime cost is an additional expense which to a large extent may be compensated when selling the stabilized sludge as a liming material. Much depends on the marketing. In many areas the price difference between limestone and quick lime is unimportant because of the difference in transport costs. The local distributions costs then are more important. At the Rya plant, as an example, the cost of stabilizing the sludge with 500 kg lime/t TS and the transport costs to the farmers within 60-65 km or 40 miles range are equal to the cost of dumping the dewatered sludge. With a fully organized marketing it should be possible to sell the stabilized sludge for agricultural purpose and pay only the difference between lime and liming material.

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